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A Southern California Gas Company Project Sage Report

Utilization Requirements

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Southern California Gas Company

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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Utilization Requirements and comparisons of two Phase III SAGE installations in California: 1) a retrofit installation in an existing apartment buidling in El Toro and 2) an installation in a new apartment building in Upland are the basis of this report. Such testing in the field reveals the requirements which must be met if SAGE-type installations are to become commercially practical on a widespread basis in electric and gas energy usage.

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PREFACE

Project SAGE has as its goal to define the equipment design, cost requirements, government policies and initiatives, market requirements, and institutional changes for successful commercial application of solar-assisted gas energy (SAGE) water heating.

The project is being conducted by the Southern California Gas Company (GASCO) in several phases, using the skills of the Environmental Quality Laboratory (EQL) and Jet Propulsion Laboratory (JPL) of the California Institute of Technology; industry; and consultants from the School of Architecture and Urban Planning and the Institute of Government and Public Affairs of the University of California, Los Angeles (UCLA).

Project SAGE is defined by a multidisciplinary team focusing on the broad problem of introducing solar energy into the U.S. building industry on a scale which could have a significant impact on the demand for fossil fuels. The regional character of the building industry leads to focusing the effort on Southern California. For the residential sector and for Southern California, water heating is a significant consumer of energy - 27% of residential energy, or 6% of primary energy. Water heating in apartments is the most likely application of solar energy to become economically competitive in the near term. In addition, a mutually beneficial relationship between solar water heating and the gas utility industry has been conceived.

In Phase 1 of Project SAGE,[1] the technical and economic feasibility of solar-assigned gas energy water heating was investigated for apartments. A point design approach was used to determine equipment and installation costs and a computer simulation model was used to estimate the performance of the system using hourly historical weather data. For a system minimizing the cost of solar energy, it was found that SAGE water heating systems have the potential to reduce the capacity required for systems to deliver natural or synthetic gas to a utility company.

The conclusions of Phase I are based on detailed cost and performance analysis of a single baseline system. Other systems are also identified in Phase I. In Phase II, the performance of the baseline systems and several alternate systems are evaluated, using experimental data from a pilot plant.[2] (The pilot plant is scaled to a ten-unit apartment.) Costs are estimated for alternate systems that are sized to give equal performance. A system is selected for further development and field testing. Finally, the designs for the system and components are established for a SAGE system which meets the life performance and cost requirements of the U.S. apartment application.

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[1] Davis, E.S., Project SAGE Phase I Report, Caltech EQL Memorandum No. 11, Pasadena, California, June 1973.

[2] Bartera, R.E., and Davis, E.S., Project SAGE Phase II Report, Design and Evaluation of Solar-Assisted Gas Energy Water Heating Systems for New Apartments, JPL Report 5030-15, January 1976.

In Phase III, the equipment is being tested in the field, and the marketing and institutional problems that challenge rapid and widespread use of SAGE water heating are being addressed. This report examines those requirements which must be met if SAGE-type installations are to become commercially practical and sufficiently widespread to have a measurable effect on electric and gas energy usage.

Since neither author is currently employed at the Jet Propulsion Laboratory, for further information contact Ralph Bartera at the Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California, 91103.

ABSTRACT

Utilization Requirements and comparisons of two Phase III SAGE installations in California: 1) a retrofit installation in an existing apartment building in El Toro and 2) an installation in a new apartment building in Upland are the basis of this report. Such testing in the field reveals the requirements which must be met if SAGE-type installations are to become commercially practical on a widespread basis in electric and gas energy usage.

CONTENTS

Tables

SECTION I

INTRODUCTION

This report is based largely on the results of the two Phase III SAGE installations in California: a retrofit installation in an existing apartment building in El Toro, and a new apartment building at Upland. Both projects used were under the same ownership and used the same design firm and plumbing contractor.

The term "Utilization Requirements" refers to those requirements that must be met if SAGE-type installations are to become commercially practical and sufficiently widespread to have a measurable effect on electric and gas usage. The emphasis is on "industry fit," - i.e., characteristics that conform to the expectations and current practices of the construction industry and its subcontractors. Because SAGE is directed to multifamily projects, its target audience is not individual homeowners or renters, but the community of people who make decisions about the design and construction of new multifamily projects and the operation of existing projects. This community includes primarily the owners and/or developers (frequently the same firm or individual) of such projects, architects and engineers who design the buildings, and the plumbing subcontractors who install water heating systems. By extension, suppliers of solar equipment and specialized subcontractors for solar installations are interested in the same types of information. For the SAGE project to have its desired effect, it must address concerns and needs of this community, which is the purpose of this report.

Earlier attempts to introduce new technology into the construction industry have demonstrated the importance of "industry fit"; new technologies that were not easily incorporated into the normal ways of doing business encountered severe difficulties or delayed commercialization. It must be recognized that the normal ways of doing business in the construction sector are both complex and highly institutionalized. A new technology must fit into this system if it is to be rapidly and widely adopted; this report identifies a set of requirements to assure that SAGE will have the required fit.

The following utilization requirements are derived in large part from the results of the two debriefing meetings for the SAGE demonstration installations. The first meeting, covering the El Toro retrofit installation, was held at El Toro, September 17, 1975 and the second, covering the Upland installation, was held at Claremont, October 20, 1976. The purpose of both meetings was to discuss first-hand information and experience derived from the projects and identify cost, technical, and construction aspects of the installations. Institutional factors that might affect future SAGE installations were also discussed.

Studies of characteristics of the building industry, energy impact analysis and policy options were also conducted in parallel with the demonstration installations and their results are incorporated in the utilization requirements presented here.

SECTION II

TECHNICAL ISSUES AND UTILIZATION REQUIREMENTS

The technical issues that affect utilization requirements will be discussed under the headings of:

- components and materials
- interface with conventional building construction and systems
- installation procedures
- demand and sizing.

All but the last of these will be discussed primarily on the basis of the experience with the two SAGE installations. Demand and sizing questions are discussed in more general terms, since the two experimental installations can provide only limited information on this point for the whole range of potential SAGE applications. Demand and sizing considerations overlap the technical and institutional issues; the results of technical analyses provide needed inputs to analyses of commercial potential.

A. COMPONENTS AND MATERIALS

A typical SAGE installation would be viewed within the construction industry as primarily a "plumbing job," with some features differing from those of the standard plumbing job. Table 2-1 lists the elements of a SAGE installation and indicates how they might be seen from the point of view of a builder or plumbing contractor. It is apparent that the only item that would be completely new and different is the collector.

As the heart of any solar energy system, the collector has received much attention in all solar energy studies and its performance and reliability are critical to the commercial feasibility of any solar installation. Since it is virtually the only element that is completely new to the building industry, it also raises questions related to union jurisdiction, interface with conventional construction, legal issues, and warranties.

Although there are already many manufacturers of solar collectors of the flat plate type used for solar-assisted water heating, the total volume of collectors manufactured is not large enough to consider their characteristics as well known. This applies to their actual thermal performance and reliability in prolonged use. Also, few if any plumbing contractors can be familiar with the special requirements or problems associated with installing them in connection with conventional water systems. One of the objectives of the SAGE Project was to acquire some

Table 2-1. Comparative Industry Uniqueness of SAGE Component Elements

Components[a]	Typical to Industry		Atypical, this Project Scale		Unique to Industry	
	Design	Install	Design	Install	Design	Install
Solar Collector Array					X	X
Storage Tank	X	X	X	X		
Tempering Tank	X	X	X	X		
Expansion Tank	X	X	X	X		
Heat Exchanger	X	X	X	X		
Differential Thermostatic Controller	X	X				
Pumps[b]	X	X				
Piping	X	X				
Water (Working) Medium	X	X			b	b

[a]See previously referenced SAGE reports for design, technical, and performance characteristics of these components.

[b]Unique if:

(1) Aluminum collector requiring an electrolytic (non-water) organic working fluid is used, or

(2) Low-carbon steel absorber plate collector requiring corrosion-inhibiting additives to the water, is used.

Source: Richard Schoen, "The Design and Specification of Low-Rise Multifamily Domestic Hot Water Heating Systems: Implications for Project SAGE," September 20, 1976 (an unpublished Project SAGE working paper).

understanding of the latter category of solar water heating system characteristics. Some of the specific issues encountered in the two SAGE installations were:

- Quality of the bond between tubing and absorber plate; poor bonding is difficult to detect but affects the performance of the collector

- Internal water leakage

- Quality of the seal between glazed cover plates and box frame (important because of the different coefficients of thermal expansion)

- Mounting of the collectors

- Ganging and manifolding the multiple collectors.

In 1975 the National Bureau of Standards published some "Interim Performance Standards for Flat Plate Solar Collectors". The most recent version of this document was published after the initial SAGE installation, but before the second one was undertaken. The test methodology used in developing these standards is not universally accepted and in any case is not within the reach of the smaller manufacturers. What is needed is an accepted industry-wide standard such as those available for most other elements of a solar water heating system; development of such a standard will be needed as a basis for widespread commercialization of these systems.

In the case of the SAGE Project, information was available from JPL studies. While this information was helpful for SAGE, it will not be available to commercial installers unless it is incorporated in a commercial standard specification. Such a specification will need to cover such matters as bonding and sealing integrity and frequency of glass breakage under all the expected conditions of manufacture, crating, shipping, handling, installation, and operation. This kind of information is needed to supplement the results of performance testing, and should also be backed up by standard test procedures.

Some collector manufacturers have added internally manifolded collectors to their lines, which should lead to greater ease and economy of installation. Any standard specification should include this type of collector as well as single modules.

The relatively large storage tank needed for a solar water heating system in a moderate-size multifamily building is normally not an off-the-shelf item even though <u>such tanks are routinely used in many applications</u> but <u>not</u> in this type of building. They are normally "fabricated" to order rather than "manufactured" in quantity. Steel, concrete, and fiberglass are common materials. Steel was chosen for the SAGE installations because it is suitable for pressurized applications and steel tanks are easier to monitor than concrete tanks (which normally would be buried below grade).

If a tank fabricator can be assured of multiple orders of identical or similar tanks, he might consider fabricating them in quantity at a lower cost than for a custom-made unit. On Project SAGE, there were leadtimes of 4 to 12 weeks on tank procurement and some modest learning and tooling costs. It should be noted that the number and location of penetrations (openings in the tank for pipes or instrumentation) is important to the fabricator, especially for glass-lined tanks, and identical tanks must have identical sizes and locations of penetrations. Special attention is needed regarding the requirements for instrumentation of the storage tank, since instruments will normally require special penetrations.

Heat exchangers are stock items, but are not strictly "off-the-shelf." A heat exchanger of specified characteristics is usually assembled from a set of stock components rather than as a unit, and is a "custom" procurement. Multiple orders could therefore be expected to result in modest reductions in lead time and cost.

The expansion and tempering tanks incorporated in the SAGE installations were stock items. The Upland installation showed that if a semi-instantaneous boiler is specified (rather than the fully instantaneous boiler normally preferred for such hydronic domestic water heating systems), a separate tempering tank is not needed. Semi-instantaneous boilers normally incorporate a small storage tank for peak loads, and this tank can perform the tempering function if it is installed in the downstream ("house loop") side of the boiler rather than in the usual upstream side.

The differential thermostatic controller is tailored to the special needs of solar water heating systems, but is only a modified version of a standard low-voltage mechanical system control. Solar controllers are available off-the-shelf and may become increasingly refined and lower in cost as solar systems multiply.

The required pumps are stock items, but because of their critical nature (a failed pump could result in freeze-up or in excessive local temperatures) it is important to have them of high quality. The pumps used in the SAGE Project were high-quality, all-bronze units.

Piping material was copper throughout, as in most current plumbing installations. Systems using two fluids could use galvanized iron or plastic pipe if permitted by codes, but there are possible electrolysis or temperature problems. Selection of piping materials is, in any case, a standard part of plumbing design.

Insulation for both pipes and tanks is important in water-heating installations, but it is available in quantity and presents no unusual problems. The importance of insulation was graphically demonstrated in the El Toro system, where analysis of data indicated that half the energy input to the conventional water heating boiler is wasted in the form of line losses in the house hot water loop.

The SAGE experience confirmed what was already known about plumbing system design. Many factors will influence the choices in a given case, reflecting the physical and economic requirements in each instance.

B. INTERFACE WITH CONVENTIONAL CONSTRUCTION AND SYSTEMS

The El Toro installation was a retrofit to an existing building, included in the SAGE Project, to bring out the problems that would arise in retrofit installations. The concern most frequently expressed in advance was that of additional loads on the roofs resulting from installation of the collectors. It was found that the added load, with collectors and piping filled with water, was not more than 6 lb/ft^2 and therefore not significant.

In the Upland installation, a new construction, the roof rafters were increased one standard lumber size in depth to provide an additional safety factor. No construction problems and an insignificant cost increase resulted.

In both cases the collectors were mounted on the roof and were relatively independent of it. Other options for mounting solar collectors are: 1) on the ground or on a building other than that being served (perhaps a central building serving a group of adjacent structures); 2) integrated into the roof structure, possibly replacing an equivalent area of roofing. The first of these options is primarily a question of esthetics versus economics and has few technical aspects other than the availability of sunlight. For roof-mounted collectors, esthetics is also a primary concern in many cases. In the Upland installation, for example, the collectors were not integrated into the roof structure but were installed as a single row in a well created for them in the roof design. The roofing material ran beneath the mountings.

When collectors are mounted directly on the roofing material, the result is many penetrations of the roofing to accommodate the collector supports. Although penetrations for plumbing and electrical fittings are common, there are standard shields and other devices to accommodate them and they occupy only a relatively small portion of the roof area. Where there are many penetrations covering a large fraction of the area, the potential for leaks is increased and the difficulties of reroofing are significantly greater.

For these reasons, roof-mounted solar collector arrays may be expected to follow the growing practice of ganging the collectors into arrays mounted on frames that span larger areas and hold the collectors well above the roof. This reduces the number of penetrations and makes reroofing simpler, but increases the cost and the visibility of the collectors.

Where collectors are integrated into the roof structure, another set of problems appears resulting primarily because the collectors must serve as a weather-tight covering in addition to their function of collecting thermal energy. The roof rafters must be designed to accommodate the collector modules (which are not standardized), and the collector modules are subject to differential thermal expansion and contraction that can easily lead to leaks. There are precedents in the form of skylights and roof access hatches that may provide useful design information or devices.

Another problem associated with integrated collectors is that they themselves carry fluids that may leak. This becomes especially important if the fluid loop through the collectors contains potentially corrosive fluids such as antifreeze solutions. This problem was not encountered in the SAGE installations, which were mounted above the roof and did not require antifreeze protection.

The large storage tank also presents some design problems. If it can be located within the building (in a basement for example), there will be no difficulty except for providing the necessary space. If it is mounted on the ground, as in the SAGE installations, it becomes an architectural element that must be accommodated. If separate from the structure it can be screened by vegetation or if within the building, it requires a removable wall panel, as in the Upland installation since it must be accessible for replacement.

Piping is not usually a concern except in retrofit installations, where the larger-than-normal pipe sizes (e.g., than size normally "going to the roof") must be accommodated.

C. INSTALLATION

Where collectors are integrated into the roof design, there will be few installation concerns other than those mentioned previously of making a weather-tight, leak-proof installation. Where collectors are mounted separately on the roof, as in the SAGE installations, roof leakage is less a concern but there are interconnection problems. At El Toro, for example, it was found that there was inadequate tolerance allowed between the collector inlets and outlets and the on-site piping. At Upland, the very long single run of collectors resulted in large thermal expansion that caused leaks between the top outlets and the header connecting them. Flexible connections were suggested for future use, but they are expensive and difficult to insulate.

If collectors are mounted on independent frames, it may become possible to mount them on the frames on the ground, or even in the plumbing shop, and run leak checks at this stage. They could then be hoisted to the roof by a light crane such as is frequently used for other purposes on multifamily projects of the type considered. This would require careful scheduling of crane availability to coincide with collector array installation. However union acceptance of this level of shop prefabrication is highly in doubt and, at this point, will require approval on a local-by-local union basis. The storage tank may also require a crane, and similar scheduling considerations would apply.

D. DEMAND AND SIZING

The sizing of a solar-assisted water heating system does not differ in principle from the sizing of a conventional system. There is evidence, however, that the sizing of a water heating system in general is a somewhat imprecise procedure that tends to err in the direction of oversizing. There are rules of thumb such as using as a basis the

number of highest-use plumbing fixtures (e.g., shower heads) in a building. There are also methods prescribed by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) that are somewhat more sophisticated but still tend to result in excess capacity; ASHRAE recommends 40 gal per day per dwelling unit. Actual hot water demand is determined by complex factors including the makeup of the population in the building to be served. Oversizing of a conventional system adds relatively little to its cost and is therefore cheap insurance against occupant dissatisfaction; in the case of solar-assisted systems, the excess capacity is reflected in considerable added investment in collectors and storage tank. It is consequently important to try to develop more accurate sizing methods as a means of eliminating unnecessary extra initial investment in solar-assisted systems.

E. SUMMARY OF TECHNICAL UTILIZATION REQUIREMENTS

Using the same categories as above, and on the basis of the preceding discussion, a set of summary utilization requirements has been formulated.

Components and Materials

(1) The considerable market pressure offered by the scope of Phase IV of the SAGE Project, plus information available from many other government-sponsored studies and demonstrations, should make it possible to encourage the accelerated development and adoption of industry-wide design and testing standards covering both performance reliability and installation of solar collectors.

(2) Detailed cost and design tradeoff studies should be made to determine whether the advances of internally headered collectors (reduced on-site labor and reduced leak potential) are in fact cost-effective.

(3) SAGE designs for different sizes and types of installations, both retrofit and new construction, should be reviewed for the purpose of establishing a limited set of storage tank designs (including materials, sizes, and penetrations) that will be applicable to a wide range of installations.

(4) Future SAGE installations should be specified with semi-instantaneous boilers, with the provision that the storage tank be incorporated in the house loop side of the boiler so that it can function as a tempering tank.

(5) SAGE systems should be designed around a set of mounting hardware and interconnecting fittings that permit any given system to be tailored to its specific requirements while making maximum use of the available manufacturing capability for different types and sizes of collectors and other components.

Interface with Conventional Building Construction and Systems

(1) Additional detailed studies should be made of techniques for mounting both roof-integrated and on-the-roof collector arrays. In the latter case, special attention should be given to independent frames that limit the number of roof penetrations and facilitate reroofing; such designs also may allow for prefabrication of complete arrays.

(2) Provision should be made for the possible incorporation of freeze protection in future SAGE installations. For this purpose, noncorrosive and nontoxic antifreeze additives should be identified and their suitability established by test.

(3) Techniques for screening or enclosing SAGE storage tanks, while retaining accessibility for service, should be identified and their relative costs and other characteristics determined.

Installation

(1) Tradeoff studies should be made of the installation of collector arrays that are assembled and tested on the ground or in a shop before being mounted on the roof.

(2) Scheduling analyses should be made to determine how the use of light cranes for installation collector arrays and/or storage tanks can be integrated into an overall construction schedule in such a way as to coordinate these crane requirements with others on the same project.

Demand and Sizing

(1) Sizing techniques for SAGE installations must be capable of handling a range of demand assumptions.

(2) Parametric studies should be made of system costs in relation to sizing, and of actual demand in specified sizes and types of projects. Current trends in industry are emphasizing energy and water conserving plumbing fixtures and devices; these should permit lower demand assumptions, which are important in light of the higher sensitivity of solar-assisted system costs to demand assumptions.

SECTION III

ECONOMIC ISSUES AND UTILIZATION REQUIREMENTS

The economic issues related to SAGE utilization requirements will be discussed under the headings of:

- initial installed costs and potential savings
- potential near- and long-term cost reductions
- first costs versus life-cycle costs.

Much of the following discussion is based on experience with the two SAGE demonstration installations, but related findings by the SAGE Project are also included.

A. INITIAL INSTALLED COSTS AND POTENTIAL SAVINGS

The cost data resulting from the El Toro and Upland demonstration installations are summarized in Tables 3-1, -2 and -3. Table 3-1 first summarizes the costs of the two installations, while Table 3-2 provides a more detailed cost breakdown. Table 3-3 restates selected cost

Table 3-1. Summary Costs of SAGE Demonstration Installations

Item	El Toro Cost		Upland Cost	
Collectors	1000 ft^2	12,670.0	936 ft^2	14,700.0
Tanks		4,100.0		4,400.0
Pumps, controller, HX, etc.		2,410.0		1,400.0
Plumbing (inc. insulation)		16,290.0		10,100.0
Design		4,800.0		1,300.0
Iron, carpentry misc.		4,280.0		1,500.0
Fredrick's profit		4,460.0		2,100.0
Gross cost		49,010.0		35,500.0
Non-solar costs		1,110.0		2,100.0
Total cost		47,900.0		33,400.0

Table 3-2. Detailed Cost Breakdown of SAGE Demonstration Installations

Item	El Toro Timbers Retrofit		Upland Woodlane New	
Collectors				
Panels (inc. shipping)	@10.80 10,900		@13.67 12,792	
Labor	1,570		894	
Mounting Equipment	200		970	
		12,670		14,656
Tanks				
Vessels	3,200		2,708	
Labor	900		1,715	
		4,100		4,423
Heat Exchanger	770		469	
		770		469
Pumps, Controller, etc.				
Pumps	a		523	
Controller ($100) and labor	a		373	
		1,640		896
Plumbing				
Pipes, valves and fittings	2,000		2,638	
Insulation	3,200		768	
Labor	3,140		1,768	
Overhead (15%) and profit 10%	7,950		3,933	
		16,290		10,107
Design				
Architectural and	2,300		337	
Engineering	2,500		1,000	
		4,800		1,337
Carpentry, Ironwork, Concrete	3,030		854	
		3,030		854
General Profit	4,460		2,053	
		4,460		2,053
Misc.	1,250		680	
		1,250		680
Non-solar costs		(2750)		(2085)
Total		47,900		33,390

[a]No separate breakdown available.

Table 3-3. Unit Cost Comparisons

	El Toro		Upland	
Total Cost	1000 ft^2	47,900	936 ft^2	33,400
Cost per apt. unit		1500.0		830.0
System cost per ft^2		48.0		35.0
Collector cost per ft^2		10.80		13.67
Collector cost (fraction of total)		27%		24%
Plumbing cost (fraction of total)		50%[a]		53%[b]
Labor cost (fraction of total)		18%[c]		23%
Labor cost per hr		21.09		22.57
Overheads and profits		27%[d]		17%
	440 hr -	9280[f]	250 hr -	5650[e]

[a]Includes $1,770 for Collector Labor

[b]Includes $4,423 for Collector Labor

[c]Includes $5,600 Plumbing Labor, $1,500 Carpentry Labor, $1,600 Insulation Labor

[d]$13,300 for Combined Leverton & Fredricks; $6,000 for Upland Combined

[e]Includes $340 for pump and controller installation and $450 for carpentry labor plus $500 for miscellaneous labor

[f]Includes $600 labor for pumps and controller plus $2000 carpentry labor and $1070 for miscellaneous labor

elements in terms that are more useful as cost and budget guidelines for project planning. These per-unit costs are finding increasing use for comparative evaluation of different solar systems (for example, total solar system installed cost as a function of installed square feet of collector area).

The cost differences between the two installations as shown in the tables appear to be attributable primarily to the following factors:

- The collector area at Upland was 6% smaller than at El Toro, but serves eight more apartment units. The smaller area at Upland reflects the finding that the El Toro installation was oversized (and therefore less cost-effective) because the ASHRAE demand estimate of 40 gal per day per unit was too high, especially for the essentially all-adult populations of both projects. The Upland project was consequently smaller throughout.

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- Inflation during the year between the bids for the two projects increased all costs for Upland in relation to El Toro. Inflation averages at least 12% annually in the construction industry.

- The El Toro installation was a retrofit, while the solar system could be integrated into the Upland design.

- The El Toro installation was truly a demonstration project, requiring extra costs for ladders, walkways, and railings for visitors to the roof.

- Both installations were made by the same plumbing contractor for the same builder/developer, with a resulting learning curve favoring the Upland installation. The JPL and GASCO personnel also benefited from its experience with the first installation.

In both cases, costs were dominated by two elements: installed collector costs were 25% of the total, and installed plumbing costs 50% the total. These are clearly elements where cost reductions can have significant leverage.

Although the collectors were basically similar in design for both installations, those at Upland cost 21% more than those at El Toro. This increase may have been due partly to inflation, but may also have reflected an increasing awareness by the manufacturers of the real cost of manufacture (capital investment and tooling, training and marketing, testing to NBS standards, etc.). Manufacturers appear to be seeking to recover these initial costs over a relatively few demonstration units, which has elicited a negative reaction from the ERDA/HUD sponsors of many demonstrations. This pressure, plus a probable growth in the market that may permit introduction of some degree of mass production, should help to bring the delivered costs of collectors down in the near future.

The insulation costs at Upland were less than 25% of those at El Toro. Some of this difference may be due to the smaller size of the Upland installation and the "straight run" design of the Upland array, and part may be due to the interior location of the Upland tank that did not require weatherproof insulation. Because the El Toro installation was a retrofit may also have contributed to the difference.

The reasons for the 38% lower plumbing cost at Upland are not entirely clear, since the systems are of essentially the same design. Probably the new construction at Upland simplified the plumbing operations, and there were also some learning curve effects that are reflected in the difference in combined builder and plumber overhead and profit — 17% at Upland versus 27% at El Toro.

Direct costs of screened tank (as at El Toro) versus fully enclosed tank (as at Upland) appeared about equal. Selection of one type of tank insulation over the other may very well depend largely on

the possible alternative uses of the area (as landscaped patios, for example), and on accessibility considerations.

The architectural and engineering fees at Upland were just over 25% of those at El Toro, but it is difficult to identify separately the contribution of JPL and GASCO to the associated effort; the figures should probably not be used as guidelines for normal commercial installations. It was clear, however, that the isometric plumbing drawings used at Upland (but not available for El Toro) were very useful. Such drawings should be provided in all cases, whether by the system engineer or the plumbing contractor. They can be expected to cost several hundred dollars for each project, but are well worth the cost.

B. POTENTIAL NEAR- AND LONG-TERM REDUCTIONS

On the basis of the discussions outlined above that followed both SAGE demonstration installations, projections have been made of probable cost reductions of future installations. These are divided into near-term reductions, assuming no new technology for solar systems, and long-term reductions assuming that cost-reducing technologies will be developed. In both cases the projections are in line with experience with other newly introduced technologies.

Table 3-4 lists the projected near-term cost reductions, based on the following assumptions:

- a 30% reduction in the cost of all-metal glazed collectors, assuming only economies of scale
- a labor learning curve that would reduce the 440 labor hr experienced by about 100 hr
- reduced overhead resulting from the learning curve of plumbing contractors ($500 per installation)
- a similar reduction of about 30% in the cost of design and engineering, resulting from standardization of system designs

Table 3-5 lists the projected long-term cost reductions, based on the following assumptions regarding new technology applied to these installations:

- all-glass collectors costing $\$5/ft^2$
- an additional labor reduction of 30 hr due to system configurations that reduce on-site labor requirements
- the same reduction in installation overhead as above
- direct purchase of the collectors, eliminating the associated overhead and profit charges

Table 3-4. Near-Term Cost Reduction Estimates, No New Technology

	El Toro	Upland
Collector cost reduction (30%)	3,801	4,400
Labor learning curve	2,650	2,080
Reduced insulation	1,000	580
Risk reduction	5,800	520
Engineering and design	2,500	500
Miscellaneous (ironwork, tanks, etc.)	———	500
Savings	15,250	8,580
Target near-term SAGE cost without new technology	32,650	25,760
	Delivered Energy Costs	
At design loads: With 15% and 10-yr life	\$15.00 per MBtu	\$11.00 per MBtu
With 8% and 20-yr life	7.50 per MBtu	6.50 per MBtu

Electricity at 3.5¢ per kWh	10.25 per MBtu
Natural gas at \$1.75 per mcf and 60% efficiency	2.90 per MBtu
New gas supply at 3-6.00 per mcf	5-10.00 per MBtu

- the same reduction in engineering and design costs as above
- reduced costs of heat exchangers and tanks resulting from a larger market for these items.

Using the assumptions of Table 3-4, the near-term cost reductions will bring the cost of new SAGE installations to \$25,760 versus the present \$33,400. The equivalent energy price at this lower cost ranges from \$6.50 to \$11.00/MBtu, depending on the financing charge assumptions. These figures make SAGE water heating in the range of competition with natural gas at \$1.50 per mcf and either new gas at \$4.50 per mcf or electricity at \$0.035 per kWh.

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C. FIRST COST VERSUS LIFE-CYCLE COST

The data in Tables 3-3, -4 and -5 are condensed in Table 3-6 to show the total costs of the El Toro and Upland installations as experienced and under the two sets of assumptions outlined above for near- and long-term cost reductions; the table also shows the cost of the SAGE installations per apartment unit. A conventional system capable

Table 3-5. Long-Term Cost Reduction Estimates With New Technology

	Savings			
	El Toro		Upland	
Collector (all glass $\$5/ft^2$)	7,900		9,980	
Labor reduction (130 hr vs 285 for installation)	3,000		3,200	
Insulation reduction	1,000		580	
Risk reduction (collectors purchased separately and no general contractor)	7,000		800	
Engineering and design	3,000		500	
Reduced piping needs	500		0	
Reduced heat exchanger and tanks	800		1,000	
Other (inc. non-solar costs)	400		500	
Savings	23,700	47,900	16,560	33,300
Long-term cost estimate with savings	24,200		16,740	

Table 3-6. Projected Installed Costs for SAGE Over Various Time Frames

	SAGE as a Function of El Toro Costs		SAGE as a Function of Upland Costs	
Time Frame of Cost Projection	Total Cost	Cost/ Apt. Unit-32	Total Cost	Cost/ Apt. Unit-40
As Installed at Demonstration	\$47,900	\$1500	\$33,400	\$830
Installed with Near-Term Cost Reductions (No New Technology)	\$32,680	\$1020	\$25,760	\$645
Installed with Long-Term Cost Reductions (New Technology)	\$24,200	\$ 755	\$16,740	\$420

of handling the full load alone would cost $150 per apartment unit, making the SAGE units look very unattractive under any set of assumptions if only first costs are considered. Even with further cost reductions in SAGE systems and increases in conventional system costs, it is unlikely that SAGE systems will ever become competitive from the first-cost point of view.

However, SAGE systems use gas only as a backup energy source under unusual conditions (prolonged cloudy spells or unusual demand, for example) and therefore exhibit much lower operating costs. Any economic comparison of conventional and SAGE systems must therefore take into account the combined first cost and operations and maintenance costs over the anticipated lifetime of the system; this is known as life-cycle costing. Although national policy considerations would favor SAGE systems over conventional systems even if the SAGE system life-cycle costs were somewhat higher than those of conventional systems, individual builders or developers are not in a position to weigh those considerations in their analyses. Methods of bringing policy considerations to bear on individual economic decisions are discussed in Section IV-F, "Energy Policy and Incentives."

A life-cycle cost analysis would result in a dollar figure per unit of energy delivered over the life of the system. Such an analysis is not necessarily of interest to a builder/developer, however. He may not plan to retain ownership of the building over the 15-20 year period of the system life cycle. In this case, he is interested primarily in keeping his first costs competitive and on this basis would favor a conventional system. Even if he plans to retain ownership, he will either provide hot water as part of the rent charge or will have it metered to each apartment and paid for separately. In the first case the tenants will have no incentive to conserve hot water, and in the second case, the hot water use has no economic effect on the builder/developer. For these reasons the builder/developer is not likely to find that a life-cycle cost analysis makes economic sense to him.

A possible solution to this problem is the adoption of regulations requiring a determination of life-cycle costs and the adoption of the system (SAGE or conventional) that shows the lowest delivered cost per unit of energy delivered over the life of the system. In this way the SAGE system, which usually has a higher first cost but a lower operating cost, would be compared on an equal basis with the conventional system with its lower first cost and higher operating cost. Such a policy has been applied by the California Coastal Zone Conservation Commission, which requires all new projects under its jurisdiction to submit a study indicating the feasibility of solar energy and its life-cycle cost comparison with conventional systems.

This policy has the advantage of not requiring the use of solar energy in projects where it is not feasible because of obstructions or other technical problems, or where its life-cycle costs are not competitive with those of conventional systems. Unfortunately this policy has encountered stiff resistance from developers, who either do not understand life-cycle costing or fear that they would not be able to sell its advantages to their customers. Such a policy is difficult to administer,

partly because any life-cycle cost analysis must make assumptions regarding fossil fuel escalation rates, solar energy maintenance costs, discount rates to be applied to the initial investment, etc. There are enough uncertainties associated with these assumptions that the outcome of the analysis can be strongly affected by the particular assumptions used and can therefore be manipulated readily.

D. SUMMARY OF ECONOMIC UTILIZATION REQUIREMENTS

The following set of condensed utilization requirements is derived from the above discussion, although not every point with economic implications is included in the list.

1. Initial Installed Costs and Potential Savings

(1) Comparative cost analyses should be made of externally headered collectors such as used in both demonstration installations and new-generation internally headered models.

(2) Similar comparative costs analyses should be made of systems using non-copper collectors and/or piping (including comparative service life). The analysis would make use of the two-fluid capability of the SAGE system, which has not been used in the demonstration installations.

(3) System cost analyses should be made using reduced demand assumptions to determine the sensitivity of system costs to this parameter.

(4) The costs of the two demonstration installations should be reviewed to determine some typical expected costs for each if the strictly demonstration nature of the projects is allowed for. This would mean subtraction of costs associated with the learning curve and with provisions for publicity (visitor facilities, movie making, etc.). The "rebid" of the Upland installation by Leverton Plumbing (commissioned by GASCO at the Upland debriefing) should be completed and the results distributed to all SAGE team members.

(5) Provision should be made in all Phase IV installations for a complete project reporting and cost breakdown mechanism and the collection of the resulting data. Items to be reported in addition to normal material and labor costs include technical design, load characteristics, identification of all participants with indication of their previous experience, and similar factors affecting actual project costs. Such a data base will permit increasingly accurate comparisons of different installations. This level of reporting detail is beyond that of standard commercial projects and will need to be funded separately. The results should be disseminated widely.

(6) Materials and equipment specifications of the type currently used in industry should be developed for all solar-specific materials and components. These should cover appropriate ranges of system parameters for expected Phase IV installations. Such specifications can then provide the basis for fair and competitive bidding by suppliers and manufacturers for Phase IV and any commercial installations outside the SAGE Project.

(7) Guidelines indicating appropriate levels of design and engineering fees for SAGE installations should be established and disseminated. No specific fees can be mandated, since there would be antitrust implications, but some indication of appropriate level will be helpful to planners of Phase IV and other installations.

2. Potential Near- and Long-Term Cost Reductions

(1) Data developed under the detailed reporting process outlined in 1(5) above should be collected, analyzed, and applied to refine the projections in Tables 3-4 and -5.

(2) The specifications developed in accordance with 1(6) above and bids based on these specifications should be monitored to determine the points where "volume breaks" (significant price reductions resulting from a given production volume) occur. Value engineering studies can then be made to determine the cost effectiveness of redesigning systems to use items that have become "stock" rather than "special order" or "custom."

(3) Parametric analyses of cost/performance/maintainability should be made for all major SAGE components to serve as a basis for quality level determination and life expectancies. These studies will permit establishment of reasonable system and component warranties.

3. First Costs Versus Life-Cycle Costs

(1) Simplified methodologies for life-cycle costing should be developed and disseminated throughout the potential SAGE market population. These should include guidance in determining fuel savings and system feasibility in a given case.

SECTION IV

INSTITUTIONAL ISSUES AND UTILIZATION REQUIREMENTS

Institutional issues can be defined as those affecting the adoption of SAGE technology that are neither technical nor economic in nature. They reflect that even a technically and economically sound new technology still depends, for its adoption on large numbers of individual decisions that are complex functions of attitudes conditioned by multiple and often intangible factors that are as important as technical and economic facts. Also, there are more formal institutional issues in the form of trade unions, legal restrictions, and government policies affecting all solar energy technology.

A. REPORTING ON PROJECT SAGE

If the completed Phase III and the projected Phase IV of Project SAGE are to have an effective influence on future individual decisions to adopt this technology, it is essential that the results of these activities be reported fully and candidly. It is especially important that costs be accurately and completely recorded because, if they are found by users to be out of line with their own experience, the value of the whole project will be brought into question. It must be remembered that Phase III of SAGE is not a marketing project that is attempting to "sell" solar energy, but a fact-finding operation that will be most effective if it engages in a frank two-way interchange of facts and opinions with the construction and plumbing industries.

Interchange with the multifamily submarket of the building industry is stressed because the decisions to use SAGE technology in this submarket will be made by key industry participants and not by individual final users (tenants) as would be the case for single-family solar energy systems. Developers and builders, architects and engineers will choose whether to adopt SAGE technology in accordance with <u>their perceptions</u> of its advantages, including the attraction it might have for prospective tenants or buyers.

Complete and detailed reporting of SAGE costs must, to be useful to the industry, clearly identify and separate those costs of demonstration projects that would not be expected in a standard commercial installation. Cost items in this category, other than those clearly related to publicity and public relations (including provision for visitors), include:

- Added instrumentation and provision for accessibility and monitoring
- Added design fees for first-time designs
- Supplier/subcontractor contingencies covering uncertainties in delivery and installation

- Persistence of a tendency to over-design ("just to make sure")
- Learning costs for skilled trades
- Supervisory time allowances (whether used or not) for special problems associated with the new technology.

The Phase III SAGE demonstrations fortunately involved a "real" builder/developer and plumbing contractor with experience in similar projects that did not include SAGE technology. Their perceptions and learning experiences were shared and recorded and were well worth any premiums they may have cost. Nevertheless, these installations were not like normal commercial jobs and the differences must be kept in mind. Until solar energy systems become routine jobs in the industry, it will be important that any projects to be let out for competitive bids to industry in general (and not confined to prequalified architects/engineers or subcontractors) provide for a pre-bid conference that will assure a thorough understanding (on the part of the bidders) of what is involved in a SAGE installation. No amount of documentation can eliminate the need for such a meeting.

One of the concerns that was explored during the SAGE demonstration projects was that of potential alternative contractual arrangements. In particular, reactions were sought to the possibility of having the gas company itself provide, install, and maintain SAGE systems. The gas company would then be stepping outside its accepted role (supplying gas and promoting the use of gas appliances) and could be seen as a competitor to the building/plumbing industry. Therefore, where the gas company (as in GASCO's service area) is perceived as a sound and responsible company, it is possible that builders would be more inclined to try this new technology when it is backed by such an organization.

No specific answers to questions of this type were developed in the course of the SAGE demonstration installations, but it appears useful to pursue them to provide a basis for utility decisions. It is easy to imagine that reactions would be a function of whether or not the respondent felt that his own interests would be threatened (e.g., the mechanical engineer or the plumbing contractor who sees "his" work being done by gas company personnel). It also is not clear at present what counteractions might be taken by people who felt themselves threatened. More research is needed in this area.

One issue that is institutional and economical (and included here even though not related to Project SAGE reporting) is that of billing for hot water in a centralized system such as is assumed for any SAGE installation. Rising costs of energy have led to an increasing trend to individual metering of units in multifamily projects. There are at present no widely accepted techniques for metering individual use of central systems of any kind, and hot water is the most common central system. Effort is needed, probably within Project SAGE, to determine the energy-conserving and profit implications of developing such techniques.

The reactions of the builder/developer, architect, and plumbing subcontractor (the same firms on both projects) are of interest as reflecting the effect of this experience on their respective attitudes. The builder/developer continued to feel, even after the second project was completed, that he would install such a system (unsubsidized) on another project only if, as an owner or firm buyer, he saw a fiscal return. He did, however, see SAGE as a potential "marketing" wedge or bargaining point to gain local zoning, planning, and/or neighborhood council approvals for a proposed project. In particular, it would be useful in this way for projects under the jurisdiction of the South Coast Regional Coastal Zone Commission, which requires that solar energy be "considered" in proposed projects.

The architect and the plumbing subcontractor expected and looked forward to future SAGE installations. It should be noted, however, that in neither case would there be a stake in the financial outcome or payoff on the investment in a SAGE system.

In summary, the information developed from the SAGE Project should be put into a form that is as useful as possible to future decision makers on the adoption of this technology; these are primarily the people responsible for the design, specification, and/or purchase of water heating and other mechanical equipment for multifamily dwellings. For projects of the scale for which SAGE is intended, these are builder/developers, architects and engineers, and plumbing subcontractors. Also, it will be useful to inform the general public so that it can apply pressure to these decision makers to consider SAGE systems as a valid option.

B. BUSINESS PLANS AND MARKETING

An important part of using Project SAGE to foster the expansion of solar-assisted water heating in multifamily buildings in Southern California (and elsewhere) is a better definition of the economics from the user's point of view, and dissemination of this information to the decision makers previously identified (builder/developers, architects and engineers, subcontractors).

One information category presently lacking is that of the market potential for SAGE systems. The rate of construction of new multifamily projects is highly variable, depending on economic conditions and population trends, but the construction industry routinely makes forecasts of new construction for planning purposes. These predictions can be used as a basis for estimating the potential market for new SAGE installations, combined with estimates of SAGE market penetration rates.

In the case of retrofit installations it is more difficult to estimate the market potential. It would be helpful if the number of existing multifamily buildings with central hot water systems could be determined and some estimate made of their potential for retrofit of SAGE systems. Such estimates for GASCO's service territory would be useful in marketing efforts, since potential subcontractors and suppliers would have some basis for their own planning and marketing; figures on the

national scale would also be valuable, although of less direct interest at this time. One possible approach might be a survey of manufacturers of central boilers or other components required for central hot water systems.

A subsector of this market that may be of interest is the renovation of existing housing projects that are in a run-down condition. SAGE systems could be proposed as part of an overall fix-up package for such projects to bring them back to the commercial market.

A secondary marketing effort should also be conducted to determine public attitudes toward solar-assisted systems in general. It would be desirable to determine the extent of renter interest in, or awareness of, solar energy for buildings and the premium (if any) they would be willing to pay to live in a solar-equipped building. Effort should be made to identify means by which any such preference could become a real market force, and to determine whether builder/developers are aware of the beginnings of public interest in their tenant populations.

It will also be necessary to define in some detail the financial aspects of SAGE systems and make this information widely available. An important step will be the preparation of detailed design and cost studies for various reasonable installation alternatives, both new and retrofit. These should include centralized as well as distributed collector arrays and integrated as well as roof-mounted arrays. This information should be provided to solar equipment suppliers so they can include it in their literature.

Part of the financial analysis should also be a determination of the extent of the trend to individual metering of hot water, since this will affect the results of decision makers' evaluation of the potential of SAGE installations.

It can be expected that commercialization of SAGE systems will involve capital costs sufficient to cover the early period when SAGE installations will not be individually profitable. Some projections are needed of "time and number of units to commercial acceptance" to serve as a basis for determination of capital requirements. The question of arrangements covering warranties, guarantees, and service responsibilities should also be examined for its financial implications.

A related question of interest is that of return on investment and/or payback period for SAGE installations. A survey should be made to determine acceptable ranges of these parameters and the potential of SAGE systems for meeting the requirements.

SAGE business plans should also include an investigation of standard as well as innovative forms of construction contractual arrangements and dissemination of this information to potential parties to such contracts. SAGE representatives should encourage precontractual familiarization conferences including all the parties, to assure thorough understanding of the special characteristics of SAGE installation before any contract is signed.

Finally, it is important that suppliers for key items in SAGE installations be selected carefully with a view to their financial stability. Their delivery capability and staying power in the market are almost as important as the quality and performance of their products.

C. DESIGN CONSIDERATIONS

Building design, including SAGE system design, covers both architectural and engineering activities. Architectural design has to do with solar system impact on the configuration and orientation of the building, especially on the form of the roof. Architects, builders, and the general public have established attitudes and perceptions that will influence the acceptability of SAGE installations and the particular form of the installation in a given case.

As noted previously, the Upland collectors were mounted in a well on the roof; this reflected the developer's idea that they should not be visible. In the El Toro retrofit installation the collectors could not be concealed, but even in new installations concealment will not necessarily be required. There is some opinion that there will be a growing tendency among architects toward bold expression of this new technology, with the collectors becoming a distinguishing architectural feature that the developer will want clearly visible. These esthetic considerations will of course have to be combined with considerations of accessibility and maintainability as is the case with other architectural features. The acceptability of solar collectors as architectural elements also may become a legal issue, as discussed below.

With regard to the engineering of SAGE systems, is has already been noted that there is an institutionalized tendency toward overdesign of central water heating systems in terms of capacity. In conventional systems this oversizing provides a margin of performance at little cost, but in SAGE systems the extra capacity comes at a cost high enough to lead to rejection of an otherwise economically sound system.

D. TRADE UNION ISSUES

Both SAGE installation debriefings indicated that systems of this kind should encounter no craft union jurisdictional problems. A SAGE system is enough like other plumbing systems and other mechanical systems in building construction so that existing rules can be applied. Even if SAGE were used for space heating, no new situations would be created from the craft union point of view.

Although no such problems were encountered in the two demonstration installations, there is a possibility of craft union reaction if collector arrays are preassembled in a factory. Certainly any attempt to "fake" internal plumbing of a collector (with perhaps only a factory-installed shroud) would lead to local union protest.

E. LEGAL ISSUES

The legal issues examined during Project SAGE included insurance, building codes, zoning and deed restrictions, and sun rights.

SAGE is enough like other building subsystems that it would be covered easily under existing types of construction-period insurance policies. The insurance question would have to be re-examined, however, in cases of third-party ownership and/or maintenance of solar system components.

Solar energy systems such as SAGE that use water as the working fluid are largely covered under existing plumbing codes with respect to temperature and pressure control, backflow, cross-connections, and other provisions to protect potable water supplies. The International Association of Plumbing and Mechanical Officials (IAPMO) has recently adopted a Uniform Solar Energy Code that includes these provisions of existing codes for water-based systems.

In the case of the two SAGE demonstration installations, the general consensus at the debriefings was that obtaining approval in accordance with the local codes did not pose any exceptional problems. A review of the debriefing reports suggests that this will not necessarily be the case in all SAGE installations, for the following reasons:

- GASCO sponsorship of the installations was a positive factor for the inspectors. They treated the installations as routine hot water systems, but at the same time were pleased to have the experience with this new type of system and believed that if any problem arose, they were "dealing with individuals who would accommodate" (i.e., GASCO and JPL).

- Building codes are often modified to prevent further recurrence of some problem that has occurred consistently. Thus if collectors or tanks in SAGE installations repeatedly leak, glass breaks, blows off, or is vandalized, or heat exchangers leak hazardous substances into water supplies, it can be expected that codes will add provisions designed to prevent such problems.

- Both SAGE installations used water throughout, but future systems may well require a two-fluid design with anticorrosion or antifreeze compounds in the collector loop. Special provisions may be necessary to meet code requirements for such systems.

- In cases where local governments have encouraged or required the installation of solar energy systems, code officials may feel that they have been put in the position of technically verifying the satisfactory operation of the systems. This it not their usual function, which is to verify only the health and safety of the systems they inspect. The reaction of code officials to this situation cannot be predicted, but it may result in some kind of inspection to enforce performance requirements as well as health and safety.

Zoning ordinances are used by local communities to control land use, and include such specifications as maximum height, set-back, buildable area in relation to lot size, and sometimes number of dwelling units allowed. They are not likely to affect multifamily, low-rise projects of the SAGE type with respect to SAGE installations.

Subdivision laws relate primarily to single-family detached houses and probably will not affect SAGE installations. There are, however, counterparts for multifamily projects called Residential Planned Developments (RPDs) or Planned Local Developments (PUDs). These require validation of proposed projects in socio-economic terms and conformance to local standards. It seems likely that SAGE systems would make RPD or PUD approval easier in most cases.

Another type of legal restriction that has a potential affect on SAGE installations is the deed restriction or Convenants, Conditions, and Restrictions (CCR). These are legal provisions written into the deed for a piece of property and purchase of the property implies acceptance of the provisions. The purpose is, in general, to assure the continuance of the "style of life" of the community, and provisions often include some relating to architectural style and appearance. These might prevent the installation of roof-mounted collectors unless some legal action is taken to negate such restrictions. Once again, these restrictions are most often applied to single-family homes and probably would not have a significant affect on multifamily projects of the SAGE type.

The last legal issue examined is that of "sun rights." The guaranteed right of property owners to even limited access to the sun stems from the "doctrine of ancient lights," and is not an American property right. There are few legal precedents and the minimal related court decisions have generally been against such rights. There has, however, been a considerable amount of research and discussion on the subject since it was first broached in 1972.

Some of the legislative actions considered, or in some cases enacted, have been solar easements, height and setback requirements included in land use and development plans, transferable solar rights, or three-dimensional zoning. None of these have been enacted in GASCO's service area. The Mayor's Solar Advisory Committee for the City of Los Angeles is monitoring developments in the field and may eventually propose some legislation.

For the moderate-density, multifamily zones where current-generation SAGE systems will find widest use, sun rights are not likely to pose a problem. Building heights tend to be relatively uniform within such zones, and few trees are initially high enough to shade the roofs of two- or three-story buildings. There are possibilities for problems in mixed zones or where trees are tall enough to shade collectors (most likely in retrofit installations).

F. ENERGY POLICY AND INCENTIVES

The major institutional influence on the speed of adoption of all solar energy systems will certainly be the public policies, including any incentives, that are adopted at all levels of government. The nature and direction of these policies cannot be determined at this time, but a number of possibilities have been identified and analyzed as part of Project SAGE activity and in many other public and private programs. The major aspects of policy and incentive measures will be reviewed briefly here.

At the present time, solar energy is nearly competitive with conventional energy sources for water heating. In some parts of the country it shows a cost advantage on a life-cycle cost basis over electric water heating, but it is not competitive with natural gas. The major reason is that natural gas is priced at an artificially low level because of pricing regulation by public bodies. The evidence suggests that deregulation of gas prices would result in increases by a factor of two to three; unregulated natural gas within Texas is selling for $1.75 to $2.20/mcf versus $0.70 to $1.00 in California. The Texas prices more nearly reflect the true marginal cost of new natural gas supplies, and if coal gasification is used as a source the estimated costs are in the range of $5/mcf with a final cost of heat delivered to the consumer of about $10/MBtu. This compares with a cost of solar water heating of about $8/Mbtu (assuming an 8% loan over a 20-year term).

Under these conditions a "rational" consumer would choose solar water heating. However, under present regulatory policies requiring "rolling in" of new, higher-cost supplies the competitive advantage of solar energy disappears. Assuming that a coal gasification plant would provide some 5% of the total supply, the result of "rolled in" pricing would raise the cost of gas from the current typical $1.50 to only $1.75/mcf on the basis of 100 M of "old" gas plus 5 M of "new" gas). The resulting cost to the consumer of $3.40/MBtu (all calculations assume a 50% efficiency) would be a bargain to the rational consumer as compared to solar water heating. This pricing method insulates the consumer from the true marginal cost of new gas supplies and acts as an institutional deterrent to the use of solar energy.

One alternative to true marginal cost pricing of natural gas (which would meet with public resistance) is the notion of utility ownership and maintenance of solar energy equipment. This concept has been examined in some detail as part of Project SAGE. Under this arrangement a utility would own the solar equipment and be responsible for installation and maintenance. The costs would be rolled into the utility's rate base, which would put solar energy on an equal footing with new energy supplies, whether gas or electric. Under a set of rules proposed by E.S. Davis of JPL, the utility would not be allowed to manufacture or install the systems but would use normal commercial channels for these activities. This provision would eliminate one source of resistance to the notion of utility ownership.

At the same time, the concept would eliminate the politically difficult results of deregulation because consumer monthly bills would not double or triple overnight but rise a moderate amount to reflect the amortized solar installation costs. It would also overcome the reluctance of builders to become involved with the uncertainties of life-cycle costing.

Other institutional means of accelerating the adoption of solar energy systems are tax incentives and low-interest loans, both of which would act to reduce the first cost of solar systems (the stumbling block in most cost comparisons not based on life-cycle costing). Parenthetically, it should be noted that few consumers, even developers of multifamily projects, are willing to look ahead 20 years for the payoff on an initial investment. Reduction of first costs makes this less important and accelerates the payoff period.

Tax incentives include tax abatements, tax credits, and accelerated depreciation allowances. Tax abatements mean the exemption of solar energy equipment from property tax and/or sales tax. The net effect is to reduce the annualized costs of solar systems by some 7 to 10%. This is not a striking reduction, but it indicates that state legislators consider the use of solar energy to be in the public interest and consequently has a high political value. More than 100 pieces of legislation to promote solar energy use have been introduced in 32 states.

Tax credits usually provide a reduction of income tax by some fraction of the amount of the initial investment in a solar system, up to some maximum. Several such bills have been introduced in Congress, with tax credits ranging from 10 to 50% of the initial investment. One bill that passed the House in 1975 (HR 6860) would have allowed a homeowner to reduce his income tax by as much as $2000 (25% of the cost of a solar installation costing up to $8000). Commercial builders could choose between a tax credit and an accelerated depreciation schedule (20% a year). They could also choose a 10% investment tax credit. The bill provided that all incentives would expire in 1981. Similar bills were introduced in the Senate and again in the House in 1976, but no legislation has yet been enacted.

Low-interest loans have also been proposed as an incentive to the adoption of solar energy systems. These are loans below commercial rates, and can alter significantly the life-cycle cost calculations for solar installations in their favor. Low-interest loan legislation has been introduced in Congress and several states are also considering using their bonding power to raise money for state-financed low-interest loans. Proposed interest rates range from 2 to about 6.5%.

The tax credit is a more direct way of providing an incentive than a low-interest loan and should have a lower administrative cost. It could, however, require more initial funding and encounter political resistance for this reason. A low-interest loan will not have this initial funding requirement and can have low administrative costs if handled through existing financial channels. Any direct financial

incentives must be administered with care to avoid or minimize possible negative effects.

One potential negative effect suggested by Roger Noll of the California Institute of Technology is that incentives might tend to discourage entrepreneurs from seeking better or cheaper techniques. The possibility of future incentive legislation may also make people who would otherwise buy a solar system wait until incentives become available. Thus if the political process delays the enactment of incentive legislation it can at the same time delay the adoption of solar energy devices by the normal market incentives.

Financial incentives should be phased out as the solar energy industry matures, since the purpose is to accelerate development rather than provide a permanent "crutch" for solar energy. Ideally, all policies should be formulated in such a way that they expire automatically when no longer needed.

One type of policy that can serve as an incentive is the promotion of information gathering and dissemination. Developers, builders, and subcontractors incur costs in acquiring the knowledge they need to specify and install solar energy systems. Both passive and active means of information dissemination can reduce these costs and thereby encourage the spread of solar energy technology.

Passive methods include the development of data banks and clearing houses for solar energy information. At present several agencies, including FEA, ERDA, HUD, and the Solar Energy Industries Association maintain some kind of data bank; a single central source would be more useful to the industry.

Passive methods merely make information available, but do not actively disseminate it to users who need it and may even be unaware of its existence. Active dissemination methods are likely to be more effective. They include focused dissemination activities and would require some intermediary between the sources of solar energy information and the user community. This intermediary would help translate solar energy information into a form that is understandable to builders and other potential users and could track and report problems encountered by users. Possible media for this kind of active dissemination are the Professional Builder, the AIA Journal, or the ASHRAE Journal. Wide circulation of solar energy journals such as the Journal of Solar Energy or the Solar Industries Association Newsletter would also be helpful. Fortunately, the responsible federal agencies seem to be aware of this problem and are designing active dissemination programs.

One type of institutional barrier to the adoption of solar energy systems is the actual or perceived risk of being one of the initial users; everyone would like someone else to be first so that he can wait until the technology is well established. The perception of risk could be reduced if the potential users were persuaded that initial projects were successful. One concept for providing and actively disseminating this type of information is the Implementation Center, an agency with the capability for independent project evaluation and policy analysis

plus information dissemination. A similar concept, called the Energy Extension Service and patterned on the Agricultural Cooperative Extension Service, has been developed by ERDA and proposed in the Senate (S3105). Demonstration projects such as those being implemented by ERDA and HUD are also valuable sources of risk-reducing information.

A suitable combination of policies and incentives that provide direct financial stimulation, effective dissemination of information, and risk reduction can provide the climate necessary for smoother adoption of solar energy systems including the SAGE type. It is still interesting to determine how large an impact such systems can have on the total energy picture and how soon it can be expected.

An attempt to answer this question has been made in the form of a market penetration model developed at JPL for Project BASE (sponsored by the Southern California Edison Company). It allows for different solar energy systems applied to a variety of residential and commercial buildings and includes the effects of energy conservation measures in modeling both conventional and solar-assisted systems. Conservation effects were included because they are the most cost-effective energy-conservation techniques and leaving them out would distort the results. The model assumes no market penetration until a solar energy system achieves a 5-year payback or an 18% internal rate of return.

G. SUMMARY OF INSTITUTIONAL UTILIZATION REQUIREMENTS

The utilization requirements arising from the institutional considerations discussed previously are summarized below. Some of the utilization requirements identified under the technical and economic categories have direct and indirect institutional implications, but will not be repeated here.

1. Reporting on SAGE

(1) All SAGE costs associated with the demonstration nature of the project (learning costs, publicity, special contingencies, overruns, etc.) should be clearly identified and separated from the costs that would be associated with any normal commercial installation. At the same time, any cost advantages enjoyed by the SAGE installations (e.g., no delay for inspection and approval) should also be identified.

(2) The projected costs of normal commercial SAGE installations should be verified by close monitoring of the actual costs of initial installations, both new and retrofit. This information, in the form of cost ranges, can then become a part of the information disseminated to decision makers.

2. Business Plans and Marketing

(1) Surveys should be made to determine the market potential for SAGE systems in GASCO's service territory (and secondarily nationwide) both for new and for retrofit installations. Renovation possibilities should be included.

(2) Public attitudes toward living in SAGE-equipped buildings should be determined.

(3) Detailed design/cost studies should be made of a range of new and retrofit SAGE installations.

(4) The extent of the trend to individual metering of hot water to apartments should be determined.

(5) Financial responsibilities of SAGE system owners and suppliers should be determined with respect to capital requirements, warranties and guarantees, and service responsibilities.

(6) Estimates should be made of return on investment and payback periods for SAGE installations and of acceptable ranges of these parameters.

(7) Various appropriate types of contractual arrangements should be identified for SAGE installations.

(8) Potential suppliers of SAGE system components should be evaluated for their financial stability.

(9) The results of the above studies should be actively disseminated to builder/developers, potential SAGE system subcontractors, architects and engineers, and solar equipment suppliers. Subcontractors and suppliers should be encouraged to incorporate the data in their standard literature.

3. Design Considerations

(1) An effort should be made to determine the kinds of design - specific information needed by professional designers, and the extent to which such information would, if available, reduce the risk and/or cost of designing SAGE-equipped buildings or designing retrofit SAGE installations.

(2) Prototype design of SAGE-equipped projects of both the in-city and garden-type apartment buildings should be developed, with specific attention to the design implications of SAGE installations. These designs should include cost estimates of the systems and of the design effort and should be in a form similar to that provided to designers for other product lines.

(3) A survey should also be made to determine designer attitudes toward solar energy systems, particularly regarding the architectural aspects of solar arrays (e.g., hidden or boldy expressed).

(4) Drawings and other data presented to professional designers should be prepared by professionals who understand the realities of solar installations in general and the SAGE system in particular. The information should include the most effective methods of collector mounting, shown in note and sketch form.

4. Trade Union Considerations

(1) SAGE systems should be designed in such a way that possible union problems on installations can be avoided. In particular, collectors should be marketed in both ganged arrays and single units to accommodate variations in local union requirements for on-site labor.

5. Legal Issues

(1) Project SAGE should monitor continuously all developments in the field of solar codes and energy-conserving design requirements at the local, state, and federal levels. Liaison should be maintained with code officials in the GASCO service territory with respect to code requirements affecting SAGE installations.

(2) The SAGE task force should also hold detailed discussions with officials of ICBO, NCSBCS, and IAPMO as well as the Los Angeles Building and Safety Department to keep aware of current thinking in those organizations on the matter of solar installations. The question of possible performance requirements (in addition to health and safety requirements) in particular should be investigated.

(3) SAGE representatives should continue their participation in Mayor Tom Bradley's Los Angeles Solar Advisory Committee deliberations, particularly with respect to possible sun rights ordinances.

(4) The code implications of using antifreeze or corrosion inhibitors in collector-loop fluids must be monitored.

6. Energy Policy and Incentives

(1) The SAGE task force should follow closely the legislative developments at the local, state, and national levels that may influence the rate of adoption of solar energy systems. To the extent that legislation finally enacted is likely to

influence the economics of SAGE systems, the effects should be incorporated in projections of SAGE commercialization.

(2) Changes in energy policy (primarily at the federal level) that appear likely to affect the economics of SAGE systems should be similarly monitored and their effects incorporated into projections.

(3) Project SAGE should remain aware of, and where appropriate participate in, federal and state programs of disseminating information on solar energy systems.

(4) GASCO should continue to evaluate the financial and legal aspects of GASCO ownership and maintenance of SAGE installations.